Boston University
School of Education
Library

The HIGH SCHOOL JOURNAL

New Trends in Science Education

THE UNIVERSITY OF NORTH CAROLINA PRESS

The HIGH SCHOOL JOURNAL

SAMUEL M. HOLTON, *Editor*
Associate Professor of Education, University of North Carolina

WILLIAM P. MATTHEWS, *Assistant Editor*
Assistant Professor of Education, University of North Carolina

EDITORIAL BOARD

L. O. ARMSTRONG
R. L. BEARD
E. C. BOLMEIER
JOHN B. CHASE, JR.
A. B. COMBS
HARRIS W. DEAN
CATHERINE T. DENNIS
G. GORDON ELLIS
J. MINOR GWYNN
A. M. JORDAN
A. K. KING
FRANKLIN H. MCNUTT
ARNOLD PERRY
E. L. PHILLIPS
GUY B. PHILLIPS
CLINTON R. PREWETT
LUTHER R. TAFF
DONALD G. TARBET

Published Monthly, October through May, by the University of North Carolina Press for the School of Education of the University of North Carolina. *Subscription Price $2.00; clubs of five to nine, $1.75 each; clubs of ten or more, $1.50 each; single copies, 40c.*

Subscriptions and Advertising are handled through the University of North Carolina Press in Chapel Hill, North Carolina, to which communications pertaining to business details should be addressed. Entered as Second-Class Matter, March 1, 1918, at Post Office at Chapel Hill, N. C., under Act of March 3, 1879.

All other communications, articles submitted for publication, and books submitted for review should be sent to *Editor, High School Journal,* Box 810, Chapel Hill, North Carolina.

The HIGH SCHOOL JOURNAL

Vol. XLIII ↖ **March, 1960** ↗ **No. 6**

IN THIS ISSUE

Improving High School Science.....*Bowen C. Dees* 302

An Accelerated Science Program
Glenn F. Powers and T. Eugene Holtzclaw 309

Science Objectives and Evaluation for Tomorrow
Lloyd B. Urdal 313

Renaissance in High School Chemistry.....*W. T. Lippincott* 320

High School Science Teaching: How Good Is It
Harold E. Ward 325

Reflective Teaching.....*Ernest F. Bayles* 329

Trends in Training in High School Chemistry
Richard Miller and Keith F. Smith 335

Book Reviews..... 343

THE CONTENTS OF THIS HIGH SCHOOL JOURNAL ARE LISTED IN "EDUCATION INDEX"

Issued Monthly, October to May, Inclusive $2.00 a Year

Published by the University of North Carolina Press for the School of Education of the University of North Carolina.

SAMUEL M. HOLTON, *Editor*

Editorial Office: Box 810, Chapel Hill, N. C.
Business Office: Box 510, Chapel Hill, N. C.

Improving High School Science

BOWEN C. DEES
Assistant Director, National Science Foundation, Washington, D. C.

AMERICA is justifiably proud of having reduced illiteracy almost to the vanishing point. Now that we have so few among us who cannot read or write, we must try to reduce the rate of scientific illiteracy: all too few graduates of our high schools today have even a reasonably accurate notion of what science is and what scientists do. In our culture there is an almost overwhelming devotion to technology and its material fruits, but only a small minority of our population distinguishes in its thinking between science itself and the important offspring of science which we call technology. Technology applies the findings of science to the many and varied wants of man: more comfortable and more durable homes and clothing, better automobiles, labor-saving processes and devices, entertainment media, and more powerful and effective weapons against disease (and against our fellowman), to name but a few.

In a way it is ironic that the present deep concern over the inadequacy of our science education is mainly due to spectacular Russian *technological* triumphs—the launching of the Sputniks. Impressive as they are, these achievements cannot accurately be described as scientific, for they belong in the same class as the development of a long-range artillery piece or the production of an improved iron lung. Few, if any, new scientific principles were involved in the building and launching of the satellites, and the basic scientific principles underlying these space exploits have been known for a long time. But the mother and daughter are not the same—nor are science and technology; yet one is dependent upon the other.

It is easy, but unsound, to think of science as having only an immediately practical, utilitarian function. The "Thinking Man" of 1960—and more especially of the years to come—cannot ignore the great truths which undergird modern science. Newton's writings must be considered as much a part of our cultural heritage as Shakespeare's. Relativity and quantum mechanics are ideas which can and must become part of the informed citizen's background in the same way that we now expect all citizens to know something about the Revolutionary war, the invention of the

telephone, and the process of electing a President. Each has a profound effect on what we are and what we do.

How can we fight scientific illiteracy? A battle of this kind must be waged simulaneously on many fronts. It requires manpower and material resources. Money in relatively large quantities will be needed to overcome existing deficiencies. Even so, the sums needed will probably amount to no more than one percent of the annual gross national product; hence the United States can easily afford to reduce its rate of scientific illiteracy to a reasonable level, if those concerned about this problem can successfully present its magnitude and importance to the American people.

Several lines of attack are open to us in our efforts to improve science education in our high schools. Four of these are discussed below.

I. Improving the subject matter knowledge of high school teachers of science and mathematics.

A shocking proportion of our high school teachers of science and mathematics have had little or no specialized training in the subjects they teach. Many others have had the amount that current certification regulations require—but these teachers have, in all too many cases, found themselves inadequately prepared to do the kind of job they want to do. Critics of our school system have placed the blame for this situation on several factors; the teacher-training institutions, state departments of education, "progressive education," "life-adjustment," theorists, and others. It is almost certain that no single factor can be held responsible for the present inadequacies in the training of science and mathematics teachers. More important, the search for a scapegoat may simply lead to fruitless recriminations without in any way improving practices. Highly desirable cooperation is not likely to thrive on a nourishment of animosity. There seems to be little reason to think that we will make our schools better by continually reiterating their faults and upbraiding those who are responsible for their operation. Positive corrective action is clearly needed.

Various steps are being taken to improve the subject-matter competence of those now teaching science and mathematics in our high school. Many programs to provide special summer training for in-service teachers in the fields have been launched in recent years. The largest effort of this sort has been supported by the Federal government through the National Science Foundation's summer institute program. Several states have also used this

mechanism, and a number of new summer programs are being tried independently by institutions of higher education.

Although summer institutes follow a variety of patterns, those who plan and operate them are asked to focus their attention sharply on the specific question: "How can the subject-matter needs of in-service high school teachers be met most effectively through an intensive short course?" The resulting programs thus emphasize improvement of teaching through giving the teachers an opportunity to learn more about what they are supposed to teach. In the NSF-supported program, the typical institute has about fifty participants and lasts approximately seven weeks. The National Science Foundation provides the host institution the funds with which to operate the institute, and also makes available an amount for participant support which usually provides a stipend of $75 per week (plus travel and dependency allowances) for each participant. In the summer of 1960 somewhat more than ten percent of the nation's high school teachers of science and mathematics will find places in these institutes.

Additional training opportunities for science and mathematics teachers who wish to improve their mastery of the subjects they teach are made available by NSF through its Academic Year Institutes program, In-Service Institutes programs, and Summer Fellowships for Secondary School Teachers.

In developing these programs for high school teachers, the Foundation has at all times emphasized the importance of improving the competence of teachers by enabling them to learn more about the specific subjects they teach. This does not mean that there is no recognition of the value of specialized pre-service training in pedagogy for such teachers. Rather, the special role which NSF tries to play is that of assuring a level of subject-matter competence on the part of each teacher such that he or she can teach more effectively and more satisfyingly. Much evidence which proves the soundness of this idea has already been accumulated.

Other moves in this general direction are being made. Several universities have instituted special post-baccalaureate, teacher-training programs which lay additional stress on thoroughly preparing graduates in the subjects they are to teach. Many universities are re-examining their teacher-training curricula and requirements for graduation from their school of education. Several states have similarly investigated the adequacy and appropriateness of their teacher certification standards. A national study of this problem

is getting under way in the American Association for the Advancement of Science.

Improving the subject matter competence of our present teachers and those who will in the future enter the profession can be an effective weapon in fighting scientific illiteracy. But we must not rely solely on this approach.

II. Course content improvement.

A tool kit which was adequate to repair a model "T" Ford is usually totally inadequate to accomplish even a relatively simple adjustment on one of Detroit's 1960 products. Although today's automobiles are in many fundamental ways similar to those made in 1915, they differ in many significant ways. Automatic transmissions, power brakes and steering, and many other refinements have made the job of the automobile mechanic increasingly specialized and complex. As technology has made the automobile more complicated, however, it has also provided the necessary materials and tools to make possible the servicing of the new products. If your new car breaks down outside the door of an old-fashioned blacksmith shop, you will probably not ask the blacksmith to make the required repairs: you may be sure that he does not have the proper tools.

Yet, as a nation, we are asking our teachers to give up-to-date instruction in science and mathematics, using as their materials—their tools—antiquated instructional materials. The textbooks we now use are too often completely outmoded. In the science courses, our laboratory materials—and the entire approach to laboratory instruction—too often have no connection with either modern science or basic principles. Most notably missing is the real spirit of the man of science, the indefinable but all-important unifying attitude which gives to students the sense that a career dedicated to the building of the edifice of objective, scientific knowledge can be both challenging and rewarding.

Again there is no quick and easy solution to this problem. It is necessary to elicit the help of some of our best scientists. Only they can provide leadership in selecting from the vast amount of material now available those items which best provide a firm and meaningful understanding of each field of science. But other kinds of experts are needed to determine what can be presented at specific educational levels and how it can be done most effectively. The informed and experienced help of science teachers, educational administrators, audio-visual experts, and others is also necessary.

Teams of workers drawn from such a variety of professional pursuits—if provided adequate financial backing—can make contributions of great importance to the improvement of the materials of instruction.

Already we can see the effects of certain moves in this direction which were begun several years ago. The Physical Sciences Study Committee, centered at MIT, has almost finished its work on a complete set of materials designed to improve instruction in physics at the high school level. (Several private Foundations have joined the National Science Foundation in supporting this endeavor.) These materials consist of a new and strikingly different text, new laboratory equipment (much of which can be constructed by the teacher or the students), a special set of supplementary films (movies which run for about 20 minutes each), and a set of "outside reading" monographs in a variety of subjects, and special teachers' guides. These so-called "PSSC materials" are being used in some 300 schools at present, and it is expected that the number of high schools using this approach to the teaching of physics will increase markedly next year. The general reaction to the new course of study has been highly favorable; student response has been remarkably enthusiastic.

The National Science Foundation is supporting several other "teams" working on the improvement of courses. The School Mathematics Study Group (which draws on mathematicians from all over the country, but has its headquarters at Yale University) is attempting to develop a new approach to the teaching of mathematics in all six grades of junior and senior high school. Similarly, NSF has made funds available to the Biological Sciences Curriculum Study (centered at Boulder, Colorado) to develop a new approach to biology for high school students. Other grants made by the Foundation are supporting course content improvement studies in chemistry and the earth sciences for the secondary school and still other studies are directed toward improving course materials for the college student.

Professional societies and individual universities are, or course, very much interested in these problems. The major hope offered by projects of the type being supported by NSF is that a considerable number of our productive scientists will come to realize that the future of their subject demands a higher quality on instruction at all levels, and that some of their time can justifiably be spent in helping to improve the materials used—even at the

high school level. Real progress has been made in achieving this goal.

All of these "curricular" studies contain an important implication: Teachers will need to learn of these developments and obtain the training necessary to make full use of the new materials being made available. Even if he has access to the newest kind of tools and the latest electronic test equipment, the blacksmith is still not the right man to choose to repair your car—unless he has had specialized training in how to use the new tools. The mutual dependence of well-prepared teachers and better tools—neither can be fully effective without the other—illustrates the need for a multi-pronged attack on the problem of improving science instruction.

III. Better school facilities.

Unless he has space for laboratory instruction, it is not enough to train a teacher in how to utilize the laboratory more effectively. Our school buildings must be arranged so as to provide the needed space and facilities for science instruction. In some of our schools, laboratory space is not a serious problem, yet there are other schools which have either inadequate laboratory space and facilities or none at all. The Federal government has launched a cooperative enterprise with the states in an effort to help provide the equipment needed to make instruction in science (and modern foreigh languages) more effective. The National Defense Education Act authorizes the U. S. Office of Education to provide matching funds to the states to enable public secondary schools to obtain instructional equipment they may need. However, neither this nor any other national program has begun to solve the problem of assuring appropriate planning in new and existing school buildings for the kind of science instruction facilities needed in schools today. Still, if the leaders in local communities can be made aware of the problem, much can be done about it.

IV. Creating a better climate for science and science instruction.

The American people generally are in love with the idea of education. However, the vital commitment to real scholarly excellence is too often missing. It is of the utmost importance that all those who are sincerely concerned with improving education in America take every opportunity to make it clear to the American people that, although our school system has done much for America, it can be and should be improved in many ways. We need des-

perately to move toward a greater respect for scholarship. Our young people should be inspired at home, as well as at school, with the need to work with diligence at the task of improving their grasp of what their forebears have thought and discovered.

Science thrives best in an atmosphere where intellectual curiosity in all fields is actively encouraged. Just as the non-scientist is afflicted with the "new illiteracy" if he knows nothing about science, so also is the scientist illiterate in another sense if he does not learn of the significant contributions of other professional groups to our society.

The British scientist-novelist, Dr. C. P. Snow, in his little book *The Two Cultures* calls attention to the fact that ". . . the intellectual life of the whole of western society is increasingly being split into two . . . polar groups: at one pole we have the literary intellectuals . . . at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension—sometimes . . . hostility and dislike, but most of all lack of understanding." Snow deplores this situation and argues that we have only a short time to set our house in order if Western culture is to continue to occupy a leading position in the world.

Just as the "literary intellectuals" must come to respect and understand a bit of science, so must John Q. Public come to realize that it is important that his children know the fundamentals of science. Because American democracy is still a dynamic and effective mechanism for expressing the will of the American people, there can be little doubt that our national efforts to improve instruction in science will be strengthened if we can convince the parents in the United States of the importance in our time of a better understanding of science on the part of specialist and non-specialist alike.

An Accelerated Science Program

GLENN F. POWERS
Chairman, Department of Physics
AND
T. EUGENE HOLTZCLAW
Dean, Division of Education, Northeast Louisiana State College

THE Committee accepts as a national goal the lifting of student performance to higher levels of excellence by greater motivation and by the provision of rewards for intellectual achievement and more adequate and extensive opportunities and challenges to the highly gifted student. To these ends we recommend that: 1. A nation-wide effort be made to pay more attention to the academically talented students (that is, those in the uper 15 to 20 per cent of their age group in intellectual ability) and to the unusually gifted students (that is, those in the upper 3 per cent of the age group). Such an effort should involve citizens, school boards, parents, teachers, together with state and national agencies, public and private. Talented students should be recognized at an early age and should be counselled in planning their educational programs and in preparing for and choosing college and university work."[1]

This statement, one of a number of recommendations of the President's Science Advisory Committee, might have been interpreted as a challenge that was anticipated and met in Monroe, Louisiana, with the initiation of an Accelerated Science Program in September, 1957.

Conceived by Mr. Robert H. Evans, now Corporate Vice President of of the Packaging Division of Olin Mathieson, the program got underway with a grant of $10,000.00 from Olin Mathieson and about $5,000 for new laboratory equipment made available by the Monroe City School Board.

At Neville High School, in Monroe, the first teacher to be brought in to conduct an accelerated chemistry course was Mr. Lon H. Colborn, from Pittsburgh, Pennsylvania. Mr. Colborn had thirty six years of successful experience teaching chemistry. The Carnegie Institute of Technology had awarded him an honorary Master of Science degree "for discovering pupils of exceptional gifts and nurturing into steady growth their full capacity for the

self-reliant pursuit of excellence in learning." Mr. Colborn remained in Monroe for two years.

The course is presently being taught by Dr. Walter S. Lapp of Lansdale, Pennsylvania. Author of numerous professional publications, Dr. Lapp also has had extensive experience including some thirty years teaching chemistry at Northeast High School, Philadelphia, Pennsylvania. In addition he has served as Lecturer-Demonstrator in Summer Institutes for Science Teachers at Rutgers University, St. Louis University, and Swarthmore College, among others.

For the first two years that the program operated, selection of students was based upon a test made by Mr. Colborn. During the 1959-60 school year the students were selected through recommendations of the principal and counselor based on the past performance of the student. Students could choose to take the class or refuse. Some refused.

The course itself differs from the other courses at Neville High School, having a two-hour class period instead of the usual fifty minute length. The teacher has only two of these double-period classes per day, and in addition is relieved of certain extra-curricular duties borne by "regular" classroom teachers at Neville.

Instead of a single textbook, several are used. Other aids such as the science section of the *New York Times* are relied upon heavily. Considerable effort has been made on the part of the teacher to stimulate interest by demonstrations and class discussion. For this course demonstrations are selected primarily for their "thought provoking" character. Students are encouraged to do a great deal of outside reading for homework, in addition to a considerable amount of problem solving.

Conventional chemistry courses are being taught (by regular local faculty) at the same time that accelerated courses are offered. Students taking the accelerated courses are most frequently juniors and seniors, but occasionally a sophomore is permitted to participate.

Almost all of the participants have had two years of high school mathematics but in exceptional cases students with only one year are included.

Major emphasis is placed on students taking part in laboratory experiences. The two hour class period is a boon to this phase of the program. Students are required to prepare their own re-

agents and in this manner gain considerable insight into the meaning of "molarity" and "normality" of solutions.

Every effort is made to stay abreast of current happenings in chemistry and related areas. This frequently results in lively class discussions which the students seem to find very stimulating.

Since it is now in its third year, the accelerated chemistry course is not considered the novelty that it was at its inception and student opinions sampled now might reflect a more conservative attitude than prevailed at that time. Students interrogated, for instance, were about evenly divided on the question of whether they would take an accelerated class in other disciplines such as English; although many felt that such courses definitely should be available. They strongly favored courses that stimulate thinking and lead to problem solving on their part.

Student response to the question, "Does the 'special' teacher do a better job?" was interesting. Most felt that he does, *primarily*, however, because the special teacher is given only two two-hour classes in the same subject per day with no other assigned duties. Many indicated that local faculty given the same opportunity could do a comparable job.

Students feel now that there is no tendency on the part of other students to treat those who are taking the accelerated course differently from any others. All indicated that they thought accelerated classes should be taught in their own schoool environment rather than handled in a special school for such students.

A very important attitude on the part of students in the accelerated course came to light during the informal questioning. The majority indicated voluntarily that they felt that grades (good or poor) were not important in such a course but that the opportunity to learn was the significant thing. Admittedly, this attitude could have been assumed by these students as being the one calculated to bring them greatest favor with the questioner, who might relay this information to their instructor! However, judging from the frankness of responses to other queries it appeared that most if not all of the students in accelerated classes seemed quite willing to voice the truth as they saw it regardless of what might be considered favorable or conventional. Perhaps this is a good indication of an early acquisition of scientific attitudes or perhaps students possessing these characteristics would tend to be the ones who would find themselves in such an accelerated science course.

By the end of the first two years of the program at Neville,

scholarships amounting to $68,000 had been received by students in the accelerated course. These students are now apparently doing very well at such schools as M.I.T., Harvard, L.S.U., Princeton, Georgia Tech., Rice, and others.

A sampling of opinion of the other teachers in the Monroe system revealed that they were definitely in favor of attention being given to the gifted student. However, they maintained some reservations regarding the way such programs might be handled; not so much from the standpoint of the actual teaching as for the method of selecting the "special teacher"; the pay, the teaching load, and in particular the extra-curricular demands on such a teacher. Although the "special teacher" is not assigned the customary extra-curricular duties he participates on a voluntary basis. The salary at present is $7,000 plus $2,000 moving expenses, and this total of $9,000 represents a higher stipend than is received by the regular faculty.

The present plan is to continue such accelerated courses, according to Mr. Van Odom, superintendent of the Monroe City school system. He feels that such courses fill a definite need in challenging the gifted students.

Other schools in Louisiana have accelerated programs, although this is the only one sponsored by Olin Mathieson in this state. Olin Mathieson sponsors similar programs in other states. Certainly this is an example of the "effort" called for by the President's Science Advisory Committee, since . . . "Such an effort should involve citizens, school boards, parents, teachers, together with state and national agencies, public and private."

Judging by the success of the program to date it would seem desirable for other systems to investigate the possibility of initiating some such program with local variations to fit local needs.

[1] "Recommendations on Talented Students, Excerpts from the President's Science Advisory Committee Report," *The Newsletter of the Inter-University Committee on the Superior Student, II* (November, 1859), 8.

Science Objectives and Evaluation for Tomorrow

LLOYD B. URDAL
School of Education, Washington State University

THE demand for more and better qualified people in science persists. Schools are placing great emphasis on teaching science in the secondary school. The Research Division of the National Education Association recently reported that out of approximately 1¼ million 1957 graduates from the public high schools, about 175,000 had completed four or more years of science and 480,000 had completed at least three years of science. The same report, however, lists: deficiencies in equipment and apparatus; difficulty in finding well-qualified teachers; need for still more curriculum development.[1]

Local school districts, state, federal and private agencies are increasing expenditures for science instruction. The National Education Association estimates that during the 1957 fiscal year secondary schools spent $30 million for equipment, apparatus and supplies.

Congress, through the National Defense Education Act of 1958, is providing significant funds for high school science-laboratory refurbishment and equipment, and assistance for both teachers and students. Harry C. Kelly, Assistant Director for the National Science Foundation, reports that the Division of Scientific Personnel in charge of program activities related to the scientific manpower was allocated a budget of $1.8 million in 1951; the same group has been allocated a budget of $66 million for 1959. The number of programs supported by the Division of Scientific Personnel has increased from one in 1951 to almost thirty in 1959.[2] Numerous private foundations and corporations also are making substantial financial resources available for the improvement of science and science instruction.

Education for the Age of Science

The Panel on Science and Engineering Education of the President's Science Advisory Committee released in May 1959, a report, *Education for the Age of Science*.[3] The Panel attempted to outline national goals in education which would strengthen education in science and engineering.

President Eisenhower, in releasing his Science Advisory Committee's report, said:

> "This report makes clear that the strengthening of science and engineering education requires the strengthening of all education. As an excellent statement of educational goals and needs, I hope it will be widely read and that it will stimulate a wider understanding of the importance of excellence of our educational system."

The Science Advisory Committee stated that, "doubling our current annual investment in education is probably a minimal rather than an extravagant goal." The committee stressed the need for joint efforts on the part of teachers, scholars, parents and citizens and that financial and moral support of the community is vital. Improvements according to the report are needed in modernizing subject matter, meeting the shortage of competent teachers and providing better opportunities for the gifted. The committee cautions that "no educational system should attempt to meet the changing fancies of each passing hour."

Priority was placed in the report on the revitalization of the course content to keep pace with current scientific advances.

Harry C. Kelly stressed the need for improving content of science courses and reported that a Physical Sciences Study Committee, supported by the Foundation is completing a project on the up-dating of high-school physics.

Science Education for all Students

Bowen C. Dees states: "All citizens must somehow achieve better understanding of what science is and what scientists do. To assure such understanding on the part of the citizens of the future is a major job which science education must attempt to accomplish. This is not a new goal, but better ways of moving toward it must be found."[4]

Considerable emphasis has been placed on the identification and training of the gifted student. Much of the discussion deals with providing special programs in science and mathematics for students who are planning to attend college. Unfortunately the e programs are available to only a few of the total school population.

However, all children of this generation obviously will live in a scientific world. General education science will assume increasing importance. Smith and Washton summarized research indicating that general education courses, particularly those replacing chemistry and physics were increasing in the public high

school. The authors note that most of these courses were developed for the junior and senior years and indicate an evident dissatisfaction with conventional chemistry as it has been taught for the non-scientists.[5]

Secondary Science Objectives

Science education goals, such as those proposed by the president's Science Advisory Committee's special panel, point to areas where improvement can be made. Improving secondary science education is resulting in: providing more science courses in secondary schools, encouraging more students to take science, providing financial assistance for students to pursue the study of sciences. Providing adequate facilities is resulting in programs of financial aid to provide additional apparatus, laboratory equipment and refurbishing laboratories. Increasing the number of completely trained teachers is resulting in special programs for science teachers and financial assistance to enable them to attend. All of these goals are providing fruitful direction for action. Furthermore, progress toward these goals can be determined in quantifiable terms.

These goals, however, do not provide all the direction that is needed to improve science education in the secondary schools. Each science teacher must decide on the basic science objectives for his course. He must relate content to the background and purposes of the students in his class. Many studies are underway or have been completed which help determine the subject matter to be taught. Less emphasis or concern has been voiced with regard to the students behavioral change resulting from instruction.

Taxonomy of Educational Objectives

Educators are aware of the difficulties of attempting to develop meaningful definitions of student behavior. Ralph Tyler, Director of the Center for the Advancement of the Behavioral Sciences, defines behavior to including thinking, acting and feeling.[6] Bloom and others, confronted with the task of providing a meaningful frame of reference to facilitate communication among educators and examiners, published *A Taxonomy of Educational Objectives*.[7] The taxonomy provides a classification of educational objectives in the cognitive domain. Running from simple to more complex behaviors usually associated with thinking, this taxonomy includes a detailed description of knowledge, abilities and skills. Different levels of knowledge range from recalling specific facts

to recalling complex theories and structures. Abilities and skills range from comprehension through application, analysis, synthesis to evaluation.

The committee recognized the cognitive domain as one of possibly three different domains. The other two were: the affective domain (probably analagous to Tyler's term feeling) which includes interest, attitudes and appreciation; and the psychomotor domain which refers to manipulatory types of behavior.

One dimension of Guilford's three dimensional model illustrating the structure of the intellect presents operation running from cognition (knowing information) through memory, divergent thinking, convergent thinking to evaluation. Divergent and convergent thinking, according to Guilford, is productive thinking.[8]

Science Objectives Should Be Scientifically Developed

Ample evidence appears in the literature to indicate that the students behavioral change and content are both important and related aspects of science objectives. In the past subject matter content considered to be important has dominated what was to be taught. Many objectives have emphasized the acquisition of factual information at the expense of development of intellectual abilities and skills, interests, attitudes and appreciations. Research findings have shown that mere memorization of facts, concepts and principles of science results in only short term retention, whereas objectives emphasizing application or other intellectual abilities and skills results in more permanent learning.

The formulation of science objectives should utilize a two way classification chart. One dimension should indicate the area and level of behavior to the changed and the other should indicate the content considered important. Such a chart will insure that both behavior and content will be considered in the development of objectives.

There is growing concern that science objectives which will encourage scientific thinking to be developed. J. Darrell Barnard, Chairman, Department of Science and Mathematics Education, New York University, states:

> "Traditionally, science has been viewed as factual. From the point of view of content, science is built upon facts. But to teach facts, in and of themselves, is not to teach science. The evidence from research clearly indicates that to teach science in this way is a waste of time and effort. It has been

found that up to 70 per cent of the specific facts learned in a science course are forgotten within one year after the completion of the course. In light of this evidence one research worker has pointed out that, since most final grades in science courses are assigned on the basis of scores made on factual examinations, the A's go to the student who forgets the most.

On the other hand when science is taught to help students understand principles and generalizations, the retention curve does not drop. Some studies indicate that it may even rise slightly above its position at the completion of the course."[9]

Science objectives which develop appropriate intellectual abilities and skills, interests, attitudes and appreciation are numerous. John B. Chase emphasizes characeristics associated with scientific attitudes as well as abilities necessary for a functional understanding of scientific method.[10] Other research indicates that critical thinking can be taught, provided those who teach are aware of the behaviors involved in critical thinking. To develop ability and skill in solving problems requires that experiences be provided for the student wherein he obtains experience in solving problems. The development of appropriate interests, attitudes, and appreciation requires learning experiences which frequently are quite different from those stressing acquisition of information. Experience also demonstrates that learning experiences can be provided which will increase knowledge as well as foster interest, attitudes, and appreciation.

Planned Evaluation

In this paper, little attention has been given to learning experiences other than to suggest that these will be determined by the science objectives for a particular course. Likewise, evoluation techniques will also be determined by the objectives formulated by the science teacher. Since science objectives should cover all areas and levels of behavior as well as content, so evaluation also must be carried out in terms of these specifications.

The two-way classification chart including behavior and content for the formulation of educational objectives should be used to provide specifications for selecting evaluation devices and determining the proportions of items to be included for each behavior and content specified. Clarence H. Nelson illustrates a test developed by using a two-way classification chart. The test is based on course objectives stressing different levels from the

"Taxonomy of Educational Objectives." In conclusion Nelson states:

> "In evaluating the outcomes of science teaching we have not begun to exhaust the potentialities of the measuring devices that we have known about for years. Testing in many quarters persists at the most primitive and slip-shod levels. To raise the level of testing and evaluation would require a restudy of objectives and teaching methods in an attempt to implement the objectives in teaching."[11]

Madeline Colhurst reports some suggestions for developing tests to measure the skill of observation, comparison, and evaluation of information.[12]

Clarence H. Boeck describes the procedures followed in developing a test. ". . . to measure the attainment of an objective related to a knowledge of and ability to use the methods of science with an accompanying scientific attitude."[13]

Numerous textbooks in measurement and evaluation suggest promising approaches in this area. Colleges and universities are improving their offerings in measurement and evaluation for prospective teachers. A recent report indicated that although a majority of institutions provided opportunity for prospective teachers to take such courses, relatively few institutions require them.

Science Today and Tomorrow

Current emphasis on and financial support for science education is resulting in numerous improvements. Science teachers are currently involved in, or have completed, extensive science curriculum studies. Federal, state, local and private agencies are giving unprecedented support to the improvement of science in the secondary schools. Much emphasis is being placed on the improvement of physical equipment and teaching materials. Special provisions are being made for the training of teachers. Concerted effort is being made to up-date science textbooks.

It is equally important, however, that emphasis be placed on the abilities, skills, attitudes, interests and appreciations people need to live in a complex scientific world. Providing appropriate learning experiences of these types is difficult, but the results are more permanent. Evidence indicates that we cannot assume that increased factual information will result in improved attitudes toward science.

Planned evaluation also is essential if we are to determine the

degree to which we are reaching our science education objectives. Some areas, particularly those dealing with attitudes and appreciations, are difficult to evaluate. Some fruitful devices, however, have been developed and others are currently providing stimulating areas of research.

The success of tomorrow's science teaching will be influenced largely by goals which point toward both desired behavioral change will be determined by the skill with which we evaluate the results and important content areas. Our progress toward these goals of our science teaching.

[1] "Science and Mathematics," *N.E.A. Research Bulletin*, XXXVI. (October, 1958), 67.
[2] Kelly, Harry C., "National Program for Education in Sciences," *School Review*, LXVII. (Winter, 1959), 396.
[3] U.S. President's Science Advisory Committee, *Education for the Age of Science*, (May, 1959).
[4] Dees, Bowen C., "Science Education in the Space Age," *Science Education*, XLII (February, 1959), 6.
[5] Smith, Herbert A., and Watson, Nathan S. "Science in the Secondary Schools," *Review of Educational Research*, XXVII (October, 1957), 343.
[6] Tyler, Ralph W. "The Functions of Measurement in Improving Instruction," *Educational Measurement*, ed. Linquist, E. F. (Washington, D. C., American Council on Education, 1951), p. 47.
[7] Bloom, Benjamin S. (ed.), *Taxonomy of Educational Objectives* (New York: Longmans, Green and Co., 1956).
[8] Guilford, J. P., Frucher, B., and Kelley, Paul H., "Developments and Applications of Tests of Intellectual and Special Aptitudes," *Review of Educational Research*, XXIX (February, 1959), 26.
[9] Barnard, J. Darrell, "Science Teaching Objectives and Methods," *The Science Teacher*, XXVI (March, 1959), 110.
[10] Chase, John B., "Helping Students Develop Scientific Methods," *The High School Journal*, XL, (February, 1957), 200.
[11] Nelson, Clarence H., "Evaluation of Objectives of Science Teaching," *Science Education*, XLIII (February, 1959), 20.
[12] Colrurst, Madeline, "Measuring Progress in Doing Skills," *School Science and Mathematics*, LIX (February, 1959), 114.
[13] Boeck, Clarence H., "An Examination of Scientific Method and Attitude," *Science Education*, XLI (March, 1957), 92.

Renaissance in High School Chemistry

W. T. LIPPINCOTT
Department of Chemistry, University of Florida

UPON examining the standard high school chemistry texts produced prior to 1957, one is impressed by two points. The first is the great care given to making the presentation of material interesting and digestible for students at this level of maturity. The second is the heavy emphasis on factual or descriptive material as opposed to the basic concepts or principles which underlie and correlate this descriptive material. For example, in one text of over 600 pages published since 1955, four pages are devoted to electron arrangements in atoms. At no other place in the book is this concept utilized, in spite of the fact that from this idea alone emerges the entire structural framework of modern chemistry. This textbook is not in a class by itself. Indeed, of ten books examined, not one author attempted to apply the ideas of atomic or molecular structure to explain the physical and chemical properties of substances—though nearly all of these authors stated in their prefaces that they had emphasized principles over descriptive material.

A significant number of teachers have testified that even though provision is made in most schools for individual differences among instructors, the textbook sets the pattern for course content. Hence one might conclude that as the textbooks go, so goes the chemistry course.

This whole situation adds up to the fact that in spite of the best intentions of textbook writers and teachers, the high school chemistry course prior to 1957, with a few noteworthy exceptions, bore very little relationship to the science of chemistry as it was viewed and practiced by modern professional chemists. Nor could this situation be remedied by simple changes, alterations or revisions in existing courses or textbooks. The missing quality was not a few skipped or easily added stitches. It was the thread itself. And this thread was the structural theory which welded the fabric of experimental facts into the still unfinished garment—the science of chemistry. It was inevitable that a renaissance in high school chemistry should occur.

This has indeed been the case. But the leadership did not

come from the high school or college teachers—those closest to the problem. Instead it came through the efforts of a few thoughtful educators who were concerned with such things as science manpower requirements in an era of technological revolution and unprecedented expansion, with mushrooming school populations and their accompanying problems, with maintaining America's leadership in science and technology. To these individuals, whose voices were virtually inaudible until they echoed resonantly and resolutely from the walls of Sputnik I, goes the credit for bringing together the college and high school people and those with adequate funds for study and experimentation.

Two major problems confronted the groups thus assembled. The first centered around approaches for improving existing course content, the second had to do with opportunities for teachers to obtain additional instruction and enerichment in subject matter. The attempts to solve these problems have produced exciting results. Since the chemists played a more important initial role in suggesting solutions to teacher enrichment problems, these will be discussed first.

The chemists, led by Dr. Otto Smith of Oklahoma State University, through the Division of Chemical Education of the American Chemical Society had begun work on teacher enrichment and updating some years earlier and were in a good position to advise the National Science Foundation on the dos and don'ts of establishing a summer institutes program. It is fair to say that the current large program of summer institutes and conferences for science teachers is, in a large measure, the result of the ground work laid by Dr. Smith and the committees of the Division of Chemical Education. This program, which has expanded from two institutes in 1953 to 379 institutes involving 18,000 teachers for the summer of 1960 is one nation-wide approach to solving the problems of teacher enrichment. For chemistry teachers this has provided an unprecedented opportunity to learn the modern outlook in the science from the participating chemists. In addition, it has given these teachers a chance to discuss common problems with one another and to plan together new approaches to teaching.

Two other attacks on the problem of teacher enrichmant are worthy of mention here. The first is Continental Classroom's *Modern Chemistry*. This is a nationally telecast chemistry course aimed primarily at teachers and designed to provide a much broader coverage of the subject than can be accomplished in most

summer institute programs. It is produced by the National Broadcasting Company and sponsored by the American Association of Colleges for Teacher Education in cooperation with the American Chemical Society. Professor John F. Baxter, on leave from the University of Florida, is the teacher. He is assisted by a staff of experienced high school teachers and by a committee of distinguished chemists. Dr. Baxter plans to have every living American who has won a Nobel Prize in Chemistry present a lesson on Continental Classroom. *Modern Chemistry* is telecast daily at 6:30 A.M. This program, like the summer institutes program, is having a profound effect on high school chemistry teaching.

Another especially important attack on teachers enrichment is directed toward pre-service teacher training and certification. Here, a great deal of work needs to be done in designing courses to meet specific needs, in streamlining curricula to include social studies, humanities and professional education courses. But most of all, a serious effort to get more science subject matter in the curriculum must be made. This is the substance of an excellent report of the Subcommittee on Teacher Certification of the Cooperative Committte on the Teaching of Science and Mathematics of the American Association for the Advancement of Science. This report was written by Professor Alfred B. Garrett of the Chemistry Departtment at Ohio State University and was published in *School Science and Mathematics* in April, 1959. In the report, Dr. Garrett emphasizes that, for the science teachers, at least half of the total of 120 hours of the baccalaureate program should be devoted to science and the remainder to the humanities, social studies and professional courses. The Garrett report has been well received by many professional groups including those studying science problems at the Kansas City Teacher Education and Professional Standards Conference. Its recommendations are already being included in teacher training curricula at many colleges.

In the preceding paragraphs some of the efforts to improve chemistry courses through teacher enrichment were discussed. While most of these efforts are not limited to chemistry problems alone, the chemistry teachers have benefited greatly from them and chemists have provided both leadership and assistance in establishing them. However, teacher enrichment is not the whole answer. Those studying the broad problem of improved science education realized that major course content changes were also necessary. In the following paragraphs some attacks on this problem are discussed.

In facing this situation the majority of chemical educators felt that one single approach—such as for example, setting up what might be called THE high school chemistry course and attempting to get all teachers and school systems to follow it—was undesirable. They preferred to experiment with a variety of programs with the thought that perhaps a common core of principles would emerge and that teachers might choose any one of a number of variations on this theme depending on their particular needs. This approach seems to be working out rather well.

Perhaps the first of these programs was the "Chemistry on Film" course completed early in 1959. This is a complete high school chemistry course on film available in color or black and white. It consists of 160 twenty-eight minute lessons including hundreds of demonstrations, some concept-clinching animations and many other teaching aids not available to most teachers. Student and teacher's manuals are available as supplementary material. This project was supported by the Fund for the Advancement of Education and was produced by Encyclopedia Britannica Films. This team had previously supported and produced tthe "Physics on Film" course. The film chemistry teacher is Dr. John F. Baxter and the course itself represents a brilliant and earnest attempt to present modern chemistry with emphasis on fundamental principles. In a number of schools now offering the course, the film is shown during the first part of the period. The classroom teacher follows this with "The real work of teaching." As one teacher put it, "The instructor on the film teaches the subject . . . I teach the students."

A second new chemistry course is the so-called Chemical Bond Approach. This course, the outcome of efforts by a dedicated group of outstanding high school and college chemistry teacher working at summer institutes sponsored by the Division of Chemical Education in 1957, 1958 and 1959, is based on the fact that atoms form different types of bonds and the type of bond between atoms determines the chemical make-up of a substance. This course is now being given at nine high schools across the country on an experimental basis. At the end of the year the course will be revised as needed. Dr. Laurence Strong of Earlham College, director of the program, says students and instructors rate the course high.

Still a third attack on improving the introductory chemistry course has been going on behind closed doors at American Chemical Society meetings for over a year. An announcement of a new and very large program, geared to providing more and

better teaching aids, facile dissemination of new developments to teachers of introductory courses and possibly a series of texts and supplementary study material, is expected momentarily. This program will probably be sponsored by the National Science Foundation and will parallel similar efforts by physicists and biologists.

A somewhat different though apparently successful course content improving device is the National Science Teachers Association—American Chemical Society Cooperative Examination in High School Chemistry. This examination, prepared by a team of distinguished high school and college teachers, is designed to be given at the end of the course. Student performance can be compared with national "norms." In principle, at least, if the test is kept up to date, teachers will be encouraged to keep their courses up to date

This, then, is the present status of the rebirth in high school chemistry. A great deal more needs to be done but at least the machinery now exists for doing much of it. Dr. Harry C. Kelly, Assistant Director of the National Science Foundation for Scientific Personnel and Education, floodlighted the path ahead in science education when he wrote recently, "It is recognized that no amount of money [or institutes or new curricula] can substitute for wisdom, initiative and sustained effort in solving the problems of education in sciences." The success of the chemistry program—and of all other educational programs—depends ultimately upon the teachers and administrators in each school or college—on their vision, wisdom, industry and courage.

Science teachers and administrators need public support to make their new programs effective. But the American people cannot know of the importance or significance of sound training in science unless the teachers and administrators have the courage to bring it forcefully and continuously to their attention.

High School Science Teaching: How Good Is It

HAROLD E. WARD
Assistant Professor of Science, Marshall College, Huntington, W. Va.

RECENT revelations that Russia is advancing rapidly in science have produced a turbulent uneasiness in education. For a time we believed that we were behind no one in our capacity and ability for scientific advance. But Russian satellites, Lunik, and other scientific achievements have thrown science education and science teaching into the spotlight. Whether the high school is doing a good job has been questioned. The ability of science and mathematics teachers to direct learning, the high school curriculum, and the attitudes of high school students have also been questioned. There is widespread feeling that the aims of education should be reviewed and modified or even discarded. No doubt there is some truth and reason in this—and there may always be.

What kind of a job are high school science teachers doing? Frankly, as in any other profession, some of them are incompetent because of the lack of ability to teach, interest in teaching or preparation. On the other hand, there are thousands of well-prepared, dedicated science teachers who are doing an excellent job. Thousands of others range between these two extremes. To answer the question completely, we must view the total picture of science teaching in the United States to get a general view as to the kind of science teaching which is being done by competent teachers in secondary schools.

There is no doubt that there are thousands of high school science teachers who are not adequately prepared to teach science. Gardner and Davis[1], in a study of the preparation of high school science teachers, found that science teachers were so poorly prepared so as to constitute a national crisis. Adding to the roll of poor teachers are those who are teaching out of their field and those who just aren't interested in teaching. Inadequate finances, shortage of teachers, lack of facilities and equipment add to the over-all problem.

Although one is forced to admit that there is considerable room for improvement of the teaching ability of secondary school teachers (this is true of any teaching staff or faculty), some good science

teaching is being done. Yet, the good teachers have suffered under the withering criticism of science teaching from some quarters. They welcome the criticism of individuals who are genuinely interested in secondary education; they detest the criticism of those who have no other objective than to sell books or to accomplish some other selfish purpose.

Many science teachers today are dedicated to the task of producing the best possible environment for science teaching and learning. They are devoted to the task of determining the best possible methods to use in science instruction. In increasing numbers they are exchanging teaching ideas in workshops, seminars, and professional meetings. A survey of the articles appearing in our professional publications testify to the interest in methodology.

In addition, high school science teachers are developing increasing interest in and ability for teaching the atypical with special emphasis on the gifted. Many teachers are rising to the educational challenge which the gifted students present. Some programs for teaching science to the gifted are in operation. Many more will be put in operation as soon as the obstacles preventing them are removed.

Dedicated science teachers in increasing numbers are improving their ability to help young people to learn to think critically. They have faith that the person who learns to think critically will use those same skills in other activities. Through the able guidance of our outstanding science educators there is a trend toward increased emphasis on teaching for critical thinking.

Moreover, high school science teachers generally are aware of the need for curriculum changes in science. Many National Science Foundation Institute participants indicate an interest in studying the science curriculum and in doing something about it. Many of them are handicapped by antique courses of study which have been forced upon them; yet, when noteworthy science curricula come to their attention, they are ready to put them to the test under classroom situations. The number of schools employing the Physical Science Study Committee physics course is evidence of this. Ferris'[2] favorable report will no doubt accelerate the introduction of the course into other schools. Teachers are eagerly awaiting the outcome of similar course revisions in chemistry and biology. Yet, it should be noted here that the revised courses em-

ploy practices that enterprising science teachers have been using for years.

Recognizing their deficiencies in subject matter and methodology, a large number of science teachers are eager to improve their teaching ability. That thousands of them each year apply for National Science Foundation institutes and fellowships is evidence in support of this observation. Observations of institute fellows at work indicate that their interest in the institute programs are not primarily monetary; they have a sincere desire to improve themselves in order to do a better job of teaching. Moreover, in response to the interest of other foundations and industrial concerns in improving the quality of science instruction, hundreds of science teachers are refreshing and extending their knowledge in science and related fields.

In many secondary schools, science teachers are supplementing or replacing the traditional laboratory procedures with exercises which emphasize the problem-solving approach. They recognize that underlying good laboratory work must be real experiences whose outcome must be determined by the students. The "open-ended experiments" of the Manufacturing Chemists Association offer hopeful models for problem-solving exercises. These experiments reduce to a minimum the chances of the teacher "telling" the students the outcome of the exercises. This kind of learning is being extended to other fields of science.

Dedicated science teachers are ready and willing to accept the "challenge of science education," while others may never recognize it. They will continue to "wallow in ignorance"; they will continue to lower the reputation of science teaching.

Science teaching occupies a unique position in the high school and society. Not only must the training of engineers, scientists, and other technical personnel be planted in the seedbed of secondary school science, but the place and responsibilities of all individuals in a scientific society must be made apparent. Secondary school science is expected to develop scientifically literate citizens. It must teach our young people to use wisely our natural resources and the products of technology. And, through a study of science, it is hoped that young people will come to understand the impact of science on society.[3]

To continue the improvement of science teaching, science teachers need the confidence of the society which they serve; the assistance of competent individuals in business and industry, the

professions, and colleges and universities; and the financial support of the tax-paying public. Continuous evaluation and improvement of science teaching are necessary to meet the challenge of science education. Money alone will not do the job but adequate financing along with an intelligent schoool board, a first rate superintendent, and a good principle who recognize the importance of good science teaching can accelerate the rate of improvement in science teaching.

[1] Ferris, Frederick L. "An Achievement Test Report," *The Science Teacher*, 26:576-8, December 1959.

[2] Richardson, John S., "Putting Quality is a Science Program," *Virginia Journal of Education* 52: 11-15; October 1958.

[3] Gardner, Margie and John Sherman Davis., *The Preparation and Assignment of Senior High School Science Teachers in Ohio*, Unpublished Thesis, The Ohio State University, 1958.

Reflective Teaching

ERNEST F. BAYLES
Professor of Education, The University of Kansas

IT seems hardly necessary to argue that public education in this country should aim primarily at helping young people learn how to think. That proposition appears to be so widely accepted that it can virtually be taken for granted. Trouble arises only when one asks what this means for keeping school, and that is why reflective teaching is such an issue.

The word "think" is a highly common one; few adult vocabularies fail perhaps to include it. But it is a variously used word and I expect that a majority of users would be surprised to find how many different meanings they themselves, as well as others, attach to it. You might sometimes find it a good exercise in semantics to analyze the hodge-podge of definitions given in almost any good dictionary. (Note that a *good* one is specified). First, it is a mere statement of belief or opinion: I think it will rain. What do you think of vegetarians? Second is a mere act of memory: I cannot think of his name. Third is employment of an idea, working out its logical consequences, logical deduction: If A is below B and B is below C, what direction is A from C? Fourth is problem solving or reflection, a process of coming to know when one neither knows already nor is sure of what idea or principle to employ in coming to know; an inductive-deductive process; Dewey's "complete act of thought."

Since context ordinarily makes clear when one is using the first meaning, we may disregard it for now. If however we are to be clear as to what it means to teach people how to think, we must distinguish between remembering, applying, and discovering. For the second meaning, therefore, we shall use the term *memory-level* thinking; for the third, *understanding-level* thinking; and for the fourth, *reflection-level* (or reflective) thinking.

Once a given case of mental activity is designated or referred to as memory or memory-level, few teachers fail to know what is meant. Between understanding and reflection levels, however, confusion is rife. And this situation is responsible for widespread failure on the part of science-education personnel to achieve clear comprehension of how we have to conduct classes if we are to "help

young people learn how to think." Ever since the mid-twenties, the literature on science education has represented insistence that understanding of principles should be sought; as opposed to memorization of factual details. But even today there seem to be few who realize that to help youngsters learn scientific principles (understanding level) does not *necessarily* help them learn how to think (reflection level), or to become genuinely scientific-minded persons.

Understanding-level thinking is indeed a projection into the unknown, for it represents a process of going "from the known to the unknown." If I understand the formula $s = 1/2gt^2$, I can predict very accurately how far a freely falling object will travel in 2.23 seconds, even though I do not already know. But I do not have to mull or turn the matter over in my mind; I do not have to reflect. I have merely to take sufficient time to perform the mathematical computation and I am in possession of a new bit of knowledge. In fact, this is the secret of testing for comprehension rather than for memory; simply make sure that each test-item is *novel* for the examinee yet can be handled by use or application of the principle in question, so that he cannot possibly remember the answer but has to "figure it out." This is a case of *using* what one knows rather than *repeating* what one knows. It indeed represents mental activity—so also would mere remembering—but it does not represent reflective thought.

Reflection-level (or reflective) thinking is a case of *coming to know*. It therefore has to stem from an I-don't-know situation but, more than that, from one in which one is not even immediately sure of what principle to use (or even whether any known principle is usable). Such a situation is a problematic one, and may be called a *problem*. The handling of such a situation may, therefore, be called *problem-solving*, and it seemingly is the only process which, if clarity of thought and of expression is desired, can legitimately be given that name. The common practice of textbook writers and, consequently, of teachers to call mathematical practice-exercises problems, and their solution problem-solving, would seem to be gross misapplication of these terms, for seldom do they have the characteristics of a genuine problem. Practically never does the context imply any doubt on a student's part as to what principle is to be used; all that is ordinarily involved is practice in application of a principle which has just been presented and whose use is to be learned.

A problem is, however, not *merely* an unanswered question. It is that, of course; but it is more. It is the outcome of an ongoing line of activity—either an action-line or a thought-line—which for some reason becomes arrested, by an obstacle or an entanglement, and cannot proceed until the arresting agent has been removed or cleared. A problem can, in consequence, perhaps best be characterized as *a forked-road or no-road situation.* As long as a road ahead appears clear, no problem is present and no reflection is necessary. Moreover, the disarranged parts of a jig-saw puzzle may lie in profusion before me, but for me they constitute no problem unless I am, or become, concerned with placing them in order.

Once a person really catches or comprehends the difference between understanding and reflection-level thinking, there is ordinarily little difficulty in taking the next step and seeing what differences it will make for teaching. Understanding-level *teaching,* on the one hand, begins with a question, next presents and elucidates an answer, then inaugurates a practice-period in which students learn how to use the answer to handle similar questions. Only one answer, the "right" one, is considered; the class members are carefully quarantined against "wrong" answers.

Reflection-level (or reflective) *teaching,* on the other hand represents a two-phase procedure of *problem-raising* and *problem-solving.* Both are equally important, for a learner can hardly be expected to solve a problem unless he first knows what the problem is and is rather acutely aware of what makes it a problem. Can you ordinarily make much sense out of the denouement of even so simple a problem as a television whodunit program, if you come in for the solution only and have not had opportunity to get a line on the problem? I am convinced that the major reason so few persons make any use whatever of algebraic quadratic equations is that they have never had opportunity to discover what kind of problem they are designed to solve. Reflective teaching, with its problem-raising as well as problem-solving phases, would go far toward rectification of this unhappy situation.

Reflective teaching *starts* with a question and *ends* with an answer. And, ideally, a problem-solving process takes into account several possible solutions (answers) before arriving at a preferred one. In other words, it is the *study* which determines what answer is preferable; not a decision by text book writer or teacher before the study is inaugurated. Once an ongoing line of activity is brought to a halt and a problem is posed, then possible answers

(or hypotheses) are brought up for consideration, they are examined or tested by whatever means are taken to be suitable, and a conclusion (an ending) which the study requires represents the stopping point for that study.

Most teachers, when first introduced to the possibility of this kind of teaching, quickly object that they have so much to cover that they do not have time to conduct class in so leisurely a matter. There is no question that a teacher's ingenuity will be challenged by this difficulty. Much rearrangement of subject matters and much rethinking of presentations will be necessitated. But, in actuality, a great deal more will be gained than will be lost, even in subject-matter coverage. For, by proper choice of problems, all of conventional subject matter can easily be encompassed, *and much more.* Greater encompassment is achieved for two reasons. First, since information is obtained for the purpose of testing proposed problem-solutions, a wider representation of *all* pertinent facts is required than when only one principle is to be demonstrated. Second, since information is cast into patterns so as to see what hypotheses-pattern best fits the data pattern, the information is made logical so that one set of facts tends to imply other facts rather than leaving all to stand essentially by themslves and having to be learned and remembered *by rote.* As is well known, logical learning is much easier achieved and much longer lasting than rote. A third point can also be adduced. When by reflective teaching, learners are systematically taught how to be independent—that is, how to learn by themselves—, it is to be expected that later, when unlearned or forgotten fact are needed, they will in turn be more readily obtained, used, and remembered than when reflective teaching is not employed. It is granted, of course, that as youngsters mature they will to a degree become independent or reflective even without the help of their teachers. But will they not become much more so *with* the help of their teachers?

Space limitations for this article precludes inclusion of even a brief illustration of reflective teaching. Many may be found, however, in other publications by the writer: articles in various professional magazines extending over the past thiry years or so, two textbooks in high-school science (1942 and 1947), and a college textbook in teaching theory (1950); even a couple of films under the writer's consultancy—"Using the Laboratory" and "Life in a Cubic Foot of Air"—produced by Coronet. In closing, let us note

a few of the ways in which science teaching would likely be improved, probably greatly so, by making it reflective.

First, youngsters would tend to develop a realizing sense of the method of science and of all that goes with it, because they would be experiencing a close approximation of being participating members in cooperative scientific investigations under the guidance of an able chairman such as, we hope, the teacher would be. Thus, students would see for themselves how scientific conclusions are reached, how dependable they may or may not be and how to judge their dependability, and how tough-minded scientists have to be, yet how ready to foresake previous commitments or beliefs as soon as the evidence becomes convincing.

Second, scientific principles would become much more thoroughly understood, because, as discussed above, they would be seen as solutions to rather keenly sensed difficulties and as to how they resolve the difficulties. When principles are learned outside of such contexts, they are learned poorly if at all. Verbal statements of scientific principles may be repeated by rote, but genuine comprehension comes only by giving such principles something to do and studying carefully how they do it.

Third, students would become acquainted with much more scientific information than they do when drilled in its memorization, because the facts employed in problem-solving are merely brought in, used, then laid aside. Hence, more can be included than when time is taken to hammer each fact home so as later to pass an examination on it. Yet, strange though it may at first seem, facts so treated are much better remembered (if memory-level exams should be given) than when presented and learned out of context even with benefit of extensive drill; a consequence of learning which is logical rather than rote. That this third point is true is attested by experiments reported by the writer is a forthcoming book.[1]

Fourth, as attested also by certain of these experiments, reflective teaching not only improves the performances of the better students but also of the poorer ones. In face, the poorer ones seem to respond and improve more quickly than do the better ones though, as is to be normally expected, in the long run and as a teacher gains experience students tend to profit in keeping with their various capacities. When youngsters are genuinely and really challenged in a cooperative enterprise, all tend to do what they can. A classroom problem stiff enough to be a challenge at the

75-percentile level will provide further incidental leads to the still better members, will convince the opinion-forming upper half that the classwork is worthwhile, and thereby will cause poorer members to feel likewise even though they will not catch all that the better students do. Even more, when the poorer students begin to catch the spirit of group challenge, they often come through with genuine and surprising contributions, all of which add incentive for them as well as for the rest. In these days when American schools are being criticized for not getting out of students what they possibly should, it would seem urgent that we make a concerted move toward reflective teaching.

Fifth, though not previously mentioned in this paper and not amenable to treatment here, reflective teaching would readily appear to be a major logical implication of our national commitment to democracy. For, if a person as a whole is to participate in policy making, each and every person needs to possess and continually employ as high-quality judgment as he can. Hence, schools in a democracy should do all they possibly can toward improving the good judgment or wisdom of each and every prospective citizen, and this means reflective teaching; teaching people *how,* as well as what, to think.

[1] Bayles, Ernest E. *Democratic Educational Theory.* New York: Harper and Brothers, Ch. 1. To be published March, 1960.

Trends in Training in High School Chemistry

RICHARD MILLER
Chemistry Instructor, Los Angeles High School
AND
KEITH F. SMITH
Supervisor, Science and Mathematics, Los Angeles City Schools

THE QUANTITY of new available chemical information has doubled about every thirteen years during the past half century.[1] This exponential growth in chemical information requires that the chemistry teacher of today must teach a course which will be broad enough to enable his students to read and understand five times as much chemistry as the student of thirty years ago. He must prepare his students for future training in many important fields. His concern is no longer limited to the needs of the future doctor, dentist, pharmacist, engineer, research chemist, or chemistry teacher. The increasing emphasis on the study of chemistry and chemical change in the approach to the solution of the problems which confront the biological scientists illustrates the growing responsibility of the chemistry teacher to do an even better job of training the students in his classes.

How could this be brought about? Two problems have continually haunted the teacher of chemistry. How could he possibly take time for his already crowded schedule to read and learn about the new developments in chemistry? How could he possibly afford to go back to school and be taught the new chemistry when he usually found it necessary to work during summer vacations? Those who sacrificed financial advantage and attempted to take summer courses found all too often that the courses were of little real value to them as classroom teachers. This posed a real problem. How could the colleges be presuaded to plan courses which would meet the teachers' needs?

Thirty years ago the individual teacher had to face these problems very much on his own. One helpful contribution came from former students who were now in college. They could tell their teacher many things about his high school course. They could point out: what was good; what basic concepts were adequately and correctly presented; what was unnecessary or useless; where greater emphasis should be placed; what material should be added? This feed-back from the college students allowed the teacher to revise his course in high school chemistry, but placed

an added burden on his shoulders because many of the necessary concepts were not included in current high school textbooks.

The past twenty-five years have brought increasing awareness of these common problems in the Los Angeles City Schools. Many in-service opportunities have been made available to our high school teachers of chemistry. Able speakers have been brought in to speak at basic institutes. Panel discussions of common problems have been presented by experienced teachers. Demonstrations of experiments and training aids such as models and charts have been shared. The preparation and adoption of a city-wide course of study by chemistry teachers has helped to unify and modernize our teaching. The development of city-wide examinations on basic information in both first and second semester chemistry, followed by standardization and the setting of achievement norms, has helped all of us. The selection and adoption of supplemental textbooks to challenge the more able students was, we believe, a real step forward.

The role of the Division of Chemical Education of the American Chemical Society in promoting growth and coordination in the teaching of chemistry at all levels has been a factor of increasing importance during the last ten years. At the meeting of the American Chemical Society in San Francisco in 1949, Professor Otto M. Smith from Oklahoma A & M College, then Chairman of the Committee on College Teaching of the Division of Chemical Education, met with more than one hundred chemistry professors and persuaded them to organize the Pacific Southwest Association of Chemistry Teachers.[2] The original purpose of this organization was to improve the teaching of chemistry at the college level and the original membership was to include only college personnel. The need for coordination and cooperation at all levels of chemistry teaching was recognized almost from the start and, as a result, membership was extended to include high school teachers as early as 1951. About one hundred fifty members of PSACT from Southern California now participate actively in mutually helpful programs which are presented four times each year. A joint meeting of the Northern and Southern Sections is held during Christmas vacation each year. During the summer of 1959 a very successful five-day conference on the teaching of chemistry was held at Asilomar, California. This meeting was sponsored by PSACT and was made possible by a grant from the National Science Foundation. Another conference is now being planned for the summer of 1960.

The interest of the American Chemical Society in chemical education is no new development in Southern California. They have sponsored an annual competitive scholarship examination for high school students of chemistry for more than forty years. They have also offered the services of their speakers bureau to the local high schools for many years. This bureau furnishes qualified speakers who come to the school and present talks and demonstrations to science clubs, chemistry classes, and assemblies. This service has recently been augmented by many experts from local industries. These programs have helped to increase the knowledge and interest of both students and teachers.

The advent of the setting up of the National Science Foundation and the rapid expansion of the number of Summer Institutes offered is a well-known story. The announcement of summer programs for high-ability secondary school students has been sent to all high schools. What may not be common knowledge is that many of these National Science Foundation programs are sponsored by the Division of Chemical Education. The Division of Chemical Education Committee on Institutes and Conferences acts as an advisory group in planning the program. The recently announced Program of Visiting Scientists in Chemistry for High Schools is one example of the planning of the Division of Chemical Education of the American Chemical Society. All of these programs can be counted upon to increase teaching skills, student interests, and student achievement.

One of the most rewarding efforts of the Division of Chemical Education was the organization of the 1957 Reed College Conference on the Teaching of Chemistry.[3] This Conference was sponsored by the Division of Chemical Education and was financed by the Crown Zellerback Foundation. The moving spirit was that of Dr. Harry F. Lewis, Director of the Institute of Paper Chemistry, Appleton, Wisconsin. His foresight in planning this meeting, coupled with his enthusiasm and continued encouragement and support, has led to the development of a new course in chemistry. This new course is known as Chemical Bond Approach Chemistry.

A grant from the National Science Foundation enabled seventeen chemistry teachers to spend six weeks in Portland, Oregon, during the summer of 1959. The purpose of their meeting was to write the text for a new course in high school chemistry. About one thousand pages of mimeographed material was written by the members of the conference. From this sufficient material was

edited, paged, and illustrated to furnish the copy for the first five chapters, which were sent to the publisher at the close of the conference. In addition, ten experiments had been written, tested with a group of students, rewritten, and edited for publication. These published materials were shipped to the nine participating high school teachers in sufficient quantity so that they could issue to each of their students: Volume I of the text, Volume I of the Student Laboratory Guide, and a special notebook for laboratory work. Since that time Volume II of both the text and the laboratory guide have been placed in their hands. The students now have nine chapters of text material and twenty experiments. It is hoped that Volume III of the text will bring the total chapters to thirteen.

CBA Chemistry is being taught to over eight hundred students in nine high schools this year. A grant from the National Science Foundation has made this trial possible. This program is known as the Chemical Bond Approach Project and is directed by:

Dr. Laurence E. Strong, Earlham College, Richmond, Indiana
Dr. Arthur H. Livermore, Reed College, Portland, Oregon
Dr. H. Anthony Neidig, Lebanon Valley College, Anneville, Pa.
Dr. M. Kent Wilson, Tufts University, Medford, Mass.

The nine teachers and the location of their schools are:

Arnold E. Bereit, Central High School, Phoenix, Arizona
Kenneth Borst, Leonia High School, Leonia, New Jersey
James DeRose, Chester High School, Chester, Pa.
Richard L. Miller, Los Angeles High School, Los Angeles, Calif.
Henrietta Parker, Shortridge High School, Indianapolis, Ind.
Robert Shewbert, Grant High School, Portland, Oregon
Wendell H. Taylor, Lawrenceville School, Lawrenceville, N. J.
Paul Westmeyer, University of Illinois High School, Urbana, Illinois
Harold Wik, Sunset High School, Beaverton, Oregon

The very real need for a new approach to the study of chemistry is underlined by the established fact that the quantity of available literature in the field of chemistry which has been published during the last thirty years is roughly four times as great as all that had been published before the time. Could some unifying theme be found which would allow this great mass of published facts to be interrelated? What ideas could best accomplish the

purpose of enabling the student to understand the reason behind the established facts? What ideas would be most helpful in the study of chemistry? These questions were discussed by the members of the 1957 Reed Conference on Chemistry and a proposed outline was published in 1958.[4] Further discussion and consideration was given to the problem at the Wesleyan Conference in 1958.[5] The 1959 Reed Conference was the fruition of the work of these two preceding conferences.

The basic concept which had been decided upon was premised upon the belief that chemical properties and chemical change could best be understood by the consideration of chemical bonds. The three fundamental bond types chosen were: the covalent bond; the ionic bond; the metallic bond. Intermediate bond types were recognized and were to be presented as such.

The treatment of the metallic bond is the only really new bond type to be considered. The metallic bond is considered to be an electron cloud or fluid in which the positively charged kernels of the metal atoms are arranged in an orderly manner. Various arrangements of these charged kernels are considered which allow the student to understand the reason for the softness of the alkali metals of Group IA as contrasted to the hardness of the alkaline earths of Group IIA. He is helped to understand that the increase in electron holding power which is brought about by the increase in nuclear charge is counteracted by the shielding effect of electron pairs present in underlying electron shells and the inverse square effect of the greater distance from the nucleus to the outer electron shell. These considerations allow the student to understand the reasonableness of the observed facts that the elements in Group IA display generally decreasing ionization potential and increasing softness as the atomic increases. The relative ease with which the lattice within the metal can be reestablished by shifts in the electron cloud helps him to understand malleability, ductility, and flexibility. He does not have to learn these properties by rote memory—instead he can predict these properties from considerations based on his own understanding of atomic structure, atomic diameter, nuclear charge, and lattice pattern. The challenge is to his ability to reason and not to his ability to memorize.

The experiences of the nine teachers involved in the Chemical Bond Approach Project were shared at a three-day conference which was held in Phoenix, Arizona, from December 27 to December 29, 1960. The general feeling was that the new approach to

the study of high school chemistry is one which is welcomed as a real challenge by the more able students, but is not beyond the ability of the average student. The experience which has been gained by these nine teachers and their resulting recommendations are now being incorporated in the revision of the textbook. The revised text and laboratory experiments will be published in time for use with the three summer institutes for high school teachers of chemistry which are to be held at: Reed College, Portland, Oregon; Kenyon College, Gambier, Ohio; and Brown University, Providence, Rhode Island. The participating teachers will be taught the revised course and will themselves perform the laboratory work under the guidance of this year's participants. It is planned to expand the teaching of CBA Chemistry for the year 1960-61 to include 10,000 students in about fifty high schools.

The general reaction to CBA Chemistry is one of growing confidence. Grave doubts as to our ability to teach such a course were very disturbing at the outset. Doubts as to the ability of the students in our classes to learn to do the kind of reasoning required by the the new course added to our uncertainty. The reaction of the students to the course was one of bewilderment at the outset. They were amazed to find that they were expected to think and reason. They have matured rapidly and are generally very pleased to have the opportunity to meet such a challenging intellectual experience.

The success during the fall semester with two classes of thirty-five each at Los Angeles High School was so encouraging that it was decided to enroll an additional two classes in February 1960. Word of mouth advertising by the sixty students who were continuing with the second semester was responsible for the enrollment of twenty-nine students in each of the two new classes. Five of the original group who started CBA Chemistry in September, 1959 were lost due to extended illness, graduation, or transfer to another high school. At least ten students, who had taken the standard chemistry class during the first semester, asked to change to CBA Chemistry, but were regretfully refused permission to make the change.

The true worth of any new approach to the study of chemistry must be evaluated in terms of better preparation of the student to continue the study of chemistry. Time alone will give the true evaluation of CBA Chemistry. Nevertheless, an attempt is being made to determine probability of success. A series of examinations are being prepared, administered, scored, and evaluated by Edu-

cational Testing Services. In addition, scores made by the participating students on College Entrance Examinations are being accumulated and studied. It is hoped that the data obtained will suggest that CBA Chemistry is an improved approach to the teaching of high school chemistry.

The CBA Chemistry must be considered as experimental for the present. In the Los Angeles City School System the standard chemistry course has recently been revised and chemistry teachers are now using this officially adopted course of study to serve more than 10,000 beginning chemistry students each year. During the past decade enrollments in chemistry classes have been increasing at a rate of 51% faster than enrollments in all other science classes and 55% faster than total enrollment in high school. Enrollments in Los Angeles City are representative of the Southern California Region.

In keeping with the general theme of this article it should be pointed out that the standard course in high school chemistry is not incompatible with the CBA approach. The difference is one of degree of emphasis rather than of philosophy. There are several main streams of conceptual thinking which characterize the revised standard course of study in chemistry. The eight themes listed below are basic conceptual areas upon which the course is built. These areas are:

1. Atomic Structure
2. Chemical Bond
3. Oxidation-Reduction
4. Kinetic Molecular Theory
5. Avogadro's Number
6. Mole and Equivalent Concept
7. Periodic Table
8. Energy

In summary, it may be noted that the dilemma of the high school chemistry teachers with respect to the time and expense for in-service training has been resolved, in part, by the grants to high school teachers through the National Science Foundation, and the professional meetings held periodically by the PSACT and the local city schools.

New and stronger approaches to the teaching of high school

chemistry have been developed and are being tried. It may be confidently asserted that high school chemistry courses which utilize more fully the scientific and anaytical approaches are succeeding in capturing the interest of our young people who will become tomorrow's scientists and consumers of science.

[1] Strong, L. E., and Benfey, O. T., J. Chem. Educ., *37*, 29 (1960)
[2] Brantley, L. R., J. Chem. Educ., *36*, 91-92 (1959)
[3] The Reed College Conference on The Teaching of Chemiary J. Chem. Educ., *35*, 54-55 (1958)
[4] Strong, L. E., and Wilson, M. K., J. Chem. Educ., *35*, 56-58 (1958)
[5] Burford, M. G., and Lewis, H. F., J. Chem. Educ., *36*, 90-91 (1959)

Book Reviews

RACHEL P. KENISTON AND JEAN TULLY. HIGH SCHOOL GEOMETRY. Ginn and Company, 1960. $4.40.

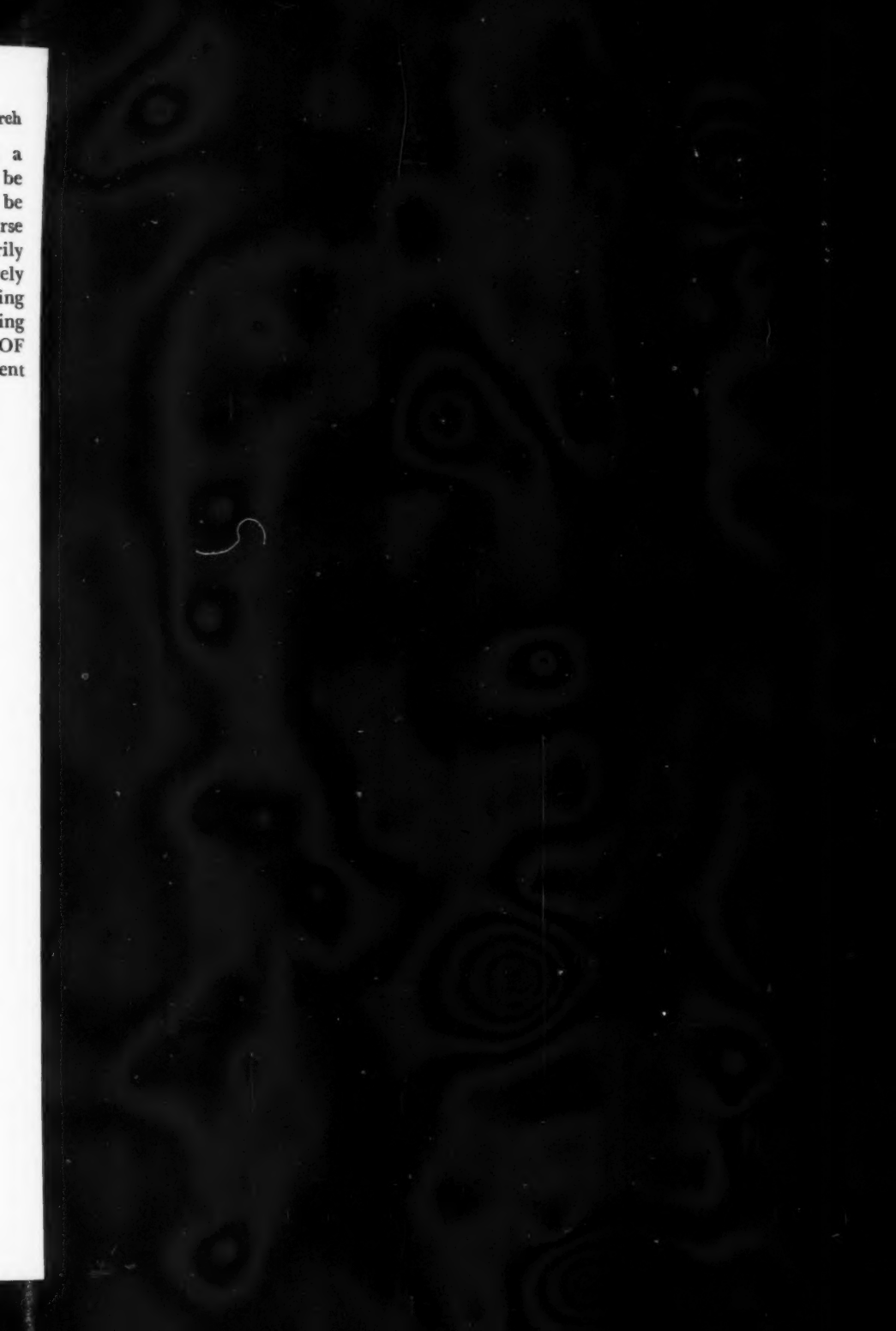
This text in high school geometry is exciting and challenging. The authors have achieved a logical development and integration of the ideas of plane geometry in relation to the total of secondary mathematics and more particularly in relation to analysis. The use of reinforcing materials from algebra and of illustrative and analogous materials from applications place this treatment in a unique position relative to geometry texts.

This text should be of maximum value to two groups of students. One is the general college-bound group with a fairly high level of motivation and a fairly high level of scholastic ability. These students should find challenge and interest and a number of leads to further study in related fields. The second group that may use this text would be an older group in mathematics who would find the sound treatment and concept development excellent background for their further work.

The material is not easy, and it will not, outside of exciting some passing interest, reach an average or slow group any more effectively than the standard geometry text and probably less effectively simple because of the relationships that must be understood to be appreciated as opposed to the traditional approach to geometry which permits considerable memorization.

Keniston and Tully introduce but do not intend to cover the areas of solid geometry and trigonometry. It is possible that through use of the paper-back discussed below, the combined plane and solid geometry might be taught using this text as a taking-off point when applications of solid geometry are introduced. The intent of the authors, however, is apparently to make solid geometry sequential to their treatment.

A. M. WELCHONS, W. R. KRICKENBERGER, AND HELEN R. PEARSON. ESSENTIALS OF SOLID GEOMETRY. Ginn and Company, 1959. $1.20.

ESSENTIALS OF SOLID GEOMETRY will constitute a substantial letdown after use of the text above. This treatment is exactly what the title implies. Basic theorms are covered, essential

proofs given, and concepts of solid geometry introduced in a traditional manner. This treatment is apparently intended to be supplementary to a pattern of plane geometry, is intended to be covered in one semester's time or as a part of the one-year course in plane or solid geometry, and as such appears to be primarily an exercise pattern in solid geometry. It is, therefore, entirely usable as a handbook or a self-teaching device for a person wishing to master elements of solid geometry. Using the motivating qualities of the book by Keniston and Tully, ESSENTIALS OF SOLID GEOMETRY might well be undertaken by a bright student as an independent study pattern.